Spacesuit and Mobility Performance Changes

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The complex interactions between the human body and spacesuit lead to changes in movement patterns and mobility performances of the wearer. In general, factors including the geometric properties, such as shape and size, mechanical properties of the suit, and pressurization of the suit are known to be associated with altered movement patterns as compared to an unsuited human. However, their relative contributions have not been explicitly quantified from the mobility performance perspectives. The goal of this study was thus to assess the effects from the different types of mobility constraint conditions, namely by wearing either a 3D printed hard upper torso (HUT) assembly or fully pressurized spacesuit. The outcome was also compared against the unsuited motions. For this study, an xEMU (exploration Extravehicular Mobility Unit) suit was considered, which is the next generation spacesuit developed by NASA.

In each test condition, the subject was asked to move the arm and hand as prescribed for different task types, and the corresponding body segment locations were recorded using a 3D motion capture system. The following three tasks were performed and analyzed: 1) Outward one-handed reaches: the subject in a standing pose made sweeping motions with the extended right arm from the extreme end-to-end positions, including side-to-side at different elevations and top-to-bottom at different azimuths. 2) Outward two-handed reaches: similar to the previous task, however the subject kept the hands together during the motions in order to assess the areas that can be reached by both hands. 3) Inward one-handed reaches: the subject made right-hand reach motions to the surface of the HUT. The hand traces collected from each task were modeled by a template shape parametrically deformed with a radial basis function. This process enabled for an abstraction of the hand traces into a smooth surface envelope representing the maximally reachable area of the test subject, of which the shapes and sizes were compared across the different test conditions.

The preliminary analysis has shown that the overall size of reach envelopes decreases in a pressurized suit compared to 3D printed mockup HUT and unsuited conditions. The specific shape of the envelopes, which were determined by the reachable and unreachable zones, also vary with the test conditions, and the differences were pronounced with the inward reaches to the HUT surface. The latter observation is potentially related to the increased demand for shoulder and elbow flexions. Overcoming the resistance from the pressurized soft goods and mechanical constraints of the shoulder assembly was seen to be associated with the difference in motion patterns between the suited and unsuited conditions. Overall, the information quantified from this study is expected to provide structured metrics for spacesuit mobility, which can improve design optimization and human-system integration.